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ABSTRACT

This paper examines the sequence and hierarchy of objectives in the American Association for the Advancement of Science (AAAS) "Science--A Process Approach" curriculum. The work of Piaget, Bruner forms a framework from which the learning objectives and tasks in the AAAS science curriculum are examined. The points of correspondence between AAAS tasks and activities and Piaget's concrete and formal operations are noted for each of the main objectives within each of the 8 basic and 6 integrated processes. Bruner's stages of enactive, ikonic, and symbolic reasoning as well as his work on concept and principle learning are also used to interpret the psychological basis for AAAS objectives and activities. The logical analysis of AAAS objectives and tasks presented shows that: (1) most objectives and tasks in the basic processes of the curriculum have an empirical basis in psychological research; and (2) many objectives and tasks in the integrated processes have little basis in psychological research. (Author)

AN INTERPRETATION OF THE SCIENCE--A PROCESS APPROACH OBJECTIVES IN TERMS OF EXISTING PSYCHOLOGICAL THEORY AND EXPERIMENTATION

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INTRODUCTION

An attempt has been made to interpret each of the American Association for the Advancement of Science (AAAS), Science--A Process Approach process objectives as they have been stated in the Commentary for Teachers (1965). The interpretation made has been in terms of existing psychological theory and research based primarily but not exclusively on the work of Piaget. The question which has been asked is, "What psychological basis do these process objectives have?". The sequential relationships between the order objectives are also examined in terms of developmental cognitive operations. A correspondence between some of the objectives and psychological theory has not been observed. Therefore, not all of the stated AAAS science objectives are meaningfully or fully interpreted. It is assumed the reader is fully familiar with the terminology of Piaget and the other psychologists referenced. It is also suggested that the reader study the paper in conjunction with the Commentary. Descriptions of the activities discussed in relation to psychological constructs are not provided in this paper.

THE BASIC PROCESS OBJECTIVES

Observing

1. Observe the properties of an object or situation using all five of your senses--This objective is clearly related to the development of perceptual activity which results in decentration. Piaget views perception as being of two opposed types. These are primary perception and perceptual activity. Primary perception involves fixation upon a particular stimulus property of a given situation. This centration causes the subject to view the feature he perceives as more significant (larger, brighter, heavier, etc.) than it really is. This is elementary error I. Elementary error II is also involved in primary perception since this error results from a lack of decentration or reinterpretation of the stimulus field. Perceptual activity reduces both elementary error I and II. When the subject is perceptually active he decenters. He constantly reinterprets the situation in a multitude of ways. He physically moves his head and body and eyes when he is visually perceiving an object. As a result of this his perception is more veridical since his perceptual activity reduces the two types of error (Flavell, 1966, pp. 234-235, 353-361).

Thus, this AAAS science objective seems to be clearly aimed at having the student decenter and reinterpret a situation in a variety of ways using all 5 of his sensory modes. An examination of the AAAS science activities reveals that this objective is intended both in a perceptual and in a logical way. Logical decentration requires a reclassification or reorganization of properties or relations. This is the very essential skill of divergent thinking or interpretation that produces the skill which Guilford (1962, p. 383) calls "flexibility" and which is vital to creative thinking or problem solution. This is also involved in Piaget's concrete operation, grouping II, the vicarious addition of secondary classes (Flavell, 1966, p. 176). It should also be noted that field dependency and field independency correspond to primary and secondary perception, i.e. to centration and decentration (Commentary, 1966, pp. 49, 62, 101, 114, 196, 203, 225). Certainly this is a very basic process skill and it is also one which is is well formulated by psychologists.

2. Exclude from your observations statements which are inferred "observations," that is, interpretations-- This objective which is aimed at the development of unbiased observations on the part of students is not

entirely possible. However, it is possible to go a long way toward the attainment of this objective. Vinacke (1951, p. 3) has discussed this problem. It is essentially one of the denotative and connotative meaning of an event or situation. The inferred part of observation is what causes the stimulus to connote what it does. The truly observable features of a situation are the denotative aspects of the situation. As both Gagné (1965, p. 48) and Vinacke (1951, p. 3) have pointed out, all interpretations of all stimuli involve both connotative and denotative meanings. However, the scientists attempts to strip interpretation of its connotative aspects leaving only a communality of denotative meaning for the interpretation of a given event, object, or situation. That this can never be fully achieved is clear from studies of perception. Piaget's work has shown the existence of secondary illusions. Certain stimuli are viewed in a non-veridical way by the subject because of the existing cognitive structure he has which adds more to the situation than is truly observable (Flavell, 1966, pp. 234, 235). The numerous studies of figural after effects may also be construed as a shorter term incidence of the same confounding of the connotative and denotative. Finally, many studies have shown that adults consistently over-compensate in

size-distance perceptual tasks and in other space-orientation tasks (Liebert & Rudel, 1959; Ittleson, 1951). Again it would seem that such compensation results from the connotative meaning of the situation, although in this case the connotative meaning may actually be a more or less denotative inference; common, say to all adults.

3. State the observations in quantitative terms whenever possible--This objective clearly involves the use of infralogical groupings and extensive quantification. The arithmetic groups, additivity and multiplicativity are also required as well as measurement operations. This objective is really contained in the objectives under the areas of Numbers, Communicating, and Measuring, and therefore will be discussed below.

4. Include observations which describe changes of properties of the object and describe the rate of these changes--This objective would seem to involve the separation of relevant variables (Inhelder & Piaget, 1958, pp. 46-66) or the isolation of defining attributes as the criterial attributes of change (Bruner, Goodnow, & Austin, 1956, pp. 25-49). This objective is really listed in more detail in the AAAS science areas of controlling variables. This objective also involves a

Classifying

1. Identify and name properties of a set of objects which can be used as a basis for a single-stage classification--This objective is clearly related to having students abstract attributes from an array of objects. Garner (1966) has studied this aspect of behavior relating to the selection of attributes for purposes of classification. Among other things Garner has shown that identification of attributes perfectly good for classification frequently does not occur. At times subjects are completely unaware of entire dimensions in a stimulus array. Bruner, Goodnow and Austin (1956) have also studied this process and call it the selection of criterial attributes which, incidentally, may or may not be acceptable for veridical classification; *i.e.* defining or non-defining. Haygood and Bourne have called this same process "attribute identification" (1965, p. 175). They too have conducted studies concerned with this process. That these studies have bearing upon this objective is clearly established by examination of the activity listed on page 60 (*Commentary*, 1965). Again notice that in this process of identifying attributes, if more than one attribute is identified decentration is required.

2. Construct one or more single-stage classifications of a set of objects--This objective is directly concerned with Piaget's concrete operation, grouping I, the primary addition of classes (Flavell, 1963, pp. 173-176). The single stage refers to the formation of only one primary and one secondary and consequently, one superordinate class; that is $A + A' = B$. This objective also demands that the subject be able to classify the objects in another way. This would involve Piaget's grouping II operation, the secondary addition of classes; that is $A_1 + A_1' = B$. Again it should be noted that the identification and selection of new attributes is required for the grouping II operation, and this in turn makes necessary both perceptual and logical decentration. The AAAS science activity on page 60 clearly calls for these process skills (Commentary, 1965).

3. Construct a two or more stage classification of a set of objects--This objective is identical to objective 2 except that the grouping I operation is extended to the formation of more than one primary, secondary and superordinate class. Each of these is placed in a hierarchy. The AAAS science activities on pages 61, 66, and 67 are nearly identical to the tasks studied by Piaget in relation to this process.

4. Use a classification system or key to identify an object--This objective relates to the use of the attributes which have been identified and selected to make a sequence of classification decisions. Therefore, it involves what Haygood and Bourne (1965) have called "rule learning" behavior. Garner has also studied this process in the use of sequential constraints in concept learning and problem solving (1962). It involves the chaining of a sequence of classification schemes. All of this is included in Piaget's primary addition of classes operation.

Space-Time Relations

It is worthwhile to note that the Science--A Process Approach commentary does not define a process for the Space-Time Relations Unit (Commentary, 1965). The objectives stated under this topic are not in themselves process objectives, but are behavioral objectives which involve basic process objectives. The exercises in this section can be grouped into four categories. These are space, time, distance and direction, and speed (Commentary, 1965, p. 78). Piaget has studied the way children think in each of these realms.

1. State the number of faces and edges of common three-dimensional shapes--This objective clearly deals

with the representation of space and not the perception of space. According to Piaget the ability to think this way is not automatic but is the product of a long developmental construction period where the actions and manipulations of the individual cause him to represent objects in terms of the "familiar" 2 and 3 dimensional shapes. Thus, the representation of a table top remains a rectangular solid even though the differing perspective of the individual constantly changes the actual perception of its shape (Flavell, 1966, pp. 327-329). The activities in this section attempt to enhance this representation (Commentary, 1965, p. 79).

2. State the two-dimensional shape which is a shadow of a three-dimensional shape held in a designated position with reference to a source of light, or the section of a three-dimensional shape made by a certain cross section--This objective clearly involves awareness of spatial perspective. The very criterion tasks stated in the objective have been specifically studied by Piaget (Flavell, 1966, pp. 330-332).

3. Sketch and name common three-dimensional shapes--This objective again involves the representation of space, rather than the perception of space. This is most apparent if one considers the true perspective of a 2 dimensional representation of a 3 dimensional object.

The preceding comments made in relation to the first objective are also relevant here.

4. *Apply a rule to demonstrate the symmetry of an object*--Again, this objective seems to be one calling for the representation of an object as two identical but reversed entities. The author knows of no psychological studies of this specific objective.

5. *Explain the importance of a frame of reference in describing changes in position*--This objective requires the realization of two conditions. First, the subject must be aware of space as a homogeneous medium which is heterogeneous with regard to filled and empty spaces over time. The space is homogeneous with respect to measurement of distance, but the space is heterogeneous with respect to position of filled spaces over time. This gives rise to the second condition, the representation of space in terms of a grid of rectilinear coordinates. Intersects upon this grid define position and thus become reference points for changes which occur through time. These conditions have been formulated and studied by Piaget in his considerations of geometry (Flavell, 1966, pp. 334-337). A conception of an uncontrolled and constant temporal sequence is also vital to this objective. Piaget points out that time

itself is eventually apprehended as a generalized homogeneous medium in which events occur in a heterogeneous manner (Flavell, 1966, p. 149). Garner (1966, p. 18) makes a similar point while discussing visual (spatial) patterns and auditory (temporal) patterns. The activities of this section of the AAAS science program seem to be devoted to the development of these cognitions (Commentary, pp. 83-88).

6. Use vectors to represent distance or speed with a designated direction and add two vectors representing direction-distance or direction-speed relations in simple situations--The representation of both time and space as discussed above are required before this objective can be achieved. In addition the bi-univocal infralogical addition and multiplication of relations is involved here. The very production of a vector involves the logical multiplication of two or more extensive quantifications or numeric relations form a common fixed reference point. The addition of vectors requires additive operations upon extensive quantities. The operations have been postulated and described by Piaget (Flavell, 1966, pp. 198-199).

7. Express the angular speed of rotating wheels and the linear speed of points on the rims of these

wheels--These objectives involve the formation of two types of specific conjunctive relationships between, 1) angular displacement/time, and, 2) distance/time. Piaget has studied the latter relationship. Again in this relationship the ability to logically multiply two independent extensive quantities is required (Flavell, 1966, pp. 318-319). One would presume this to be the case for the former relationship as well since the nature of the conjunction is the same. Only the speci[illegible] attributes used in the numerator differ. The activities of this section of the AAAS science program seem to be in general agreement with this interpretation.

Numbers

1. Demonstrate the comparison of sets using a one-to-one correspondence--This objective involves recognizing the equivalence of the extension of two sets of objectis. It has been studied extensively. It has been found to be an observable concrete behavior which precedes conservation of quantity but does not insure it. Initially children are capable of this operation only in a concrete manipulatory way. Later, with the conceptualization of number, correspondence between elements of sets is not limited to close spatial-

temporal situations (Flavell, 1966, pp. 312-313; Piaget, 1952; Wohlwill & Lowe, 1962).

2. Demonstrate the uses of the number line accurately and locate points on a number line corresponding to any number once a 0 point and a side have been chosen--This objective clearly requires the group X operation of Piaget, called the additive group of whole numbers. This operation depends upon the existence of 4 relationships, 1) Composition 1 + 1 = 2, 2 + 1 = 3; 2) associativity (1 + 1) + 1 = 1 + (1 + 1); 3) inverses such as -1, -2, and all other negative numbers; 4) identity 0, 0 + 1 = 1, 0 + 2 = 2 etc. (Flavell, 1966, pp. 171, 198). In addition, the grouping V operation of Piaget is required for this objective. This is seriation. Seriation involves the establishment of an asymmetrical ordered array of numbers of relations and transitivity is implied (Flavell, 1966, p. 180).

3. State a ratio as an ordered number pair and identify units of measure to associate with a ratio of two numbers--This objective is somewhat related to the multiple ordering of Bruner (1966, pp. 154-167) and the bi-univocal multiplication of classes (grouping III) of Piaget (Flavell, 1966, pp. 177-178). These are two different names for the same process. This process, however, is not specifically the one which is stated

in this objective, but it is prerequisite. Multiple ordering or grouping III deals with classes. A ratio deals with a relationship. Therefore, this objective is directly analogous to Piaget's grouping VII operation which involves bi-univocal multiplication of relations. This approach necessitates viewing a ratio as an ordered (asymmetric extensive quantification) pair each with their own dimensions or units (Flavell, 1966, pp. 183-185). Bruner's et. al. (1966, Chapter 8) section on relational concepts can also be interpreted as a ratio of ordered pairs, and again may be considered identical to Piaget's grouping VII. Both the discrete classification grouping III and the continuous relational grouping VII are required in SAPA activities (Commentary, 1965, pp. 101-102).

4. Identify a straight line, curve, ray, line segment, closed and open curves and angle--This objective has some similarity to the studies of Piaget concerning the categorization of spatial configurations according to topological, projective or Euclidean concepts. Topological properties include order, proximity, enclosure, and continuity and are basic to all other types of spatial categorization. Piaget has studied the topological representation used for closed and open figures, lines, and line segments. The notion of a ray involves projective considerations. Angles involve Euclidean

considerations. Both of these have also been studied by Piaget (Flavell, 1966, pp. 327-330; Piaget 1957).

5. State the relationship between the process of measuring an angle and the process of measuring length, area, or volume--This objective clearly involves the use of arbitrary infralogical elements as iterable units. This is what is common to any measurement task. The measurement process is only possible when the elements of a group iterate; that is, when one element is taken as a unit and is displaced n times along the length, volume, time or angle to be measured (Flavell, 1966, pp. 198-199).

6. Demonstrate use of scientific notation in working with small and large numbers--This author knows of no psychological theory or work which has correspondence to this objective.

Communicating

1. Construct a bar or point graph of pairs of measurement--This objective clearly requires the infralogical application of Piaget's grouping VII operation, bi-univocal multiplication of relations. This is the logical multiplication of two or more asymmetrical relations (Flavell, 1966, pp. 182-186).

2. <u>Identify the controlled measurement and the uncontrolled measurement in a table or graph of data</u>--This objective is somewhat related to Piaget's "operations" dealing with the separation of relevant variables (Inhelder and Piaget, 1958, pp. 46-66). It is also somewhat similar to Piaget's "operations" of exclusion (Inhelder and Piaget, 1958, pp. 67-79). There are two reasons why the correspondence is not clear. First these operations of Piaget are not clearly or unambiguously defined in the precise way his nine grouping and 2 group operations are. As Flavell points out in numerous places throughout his text, many of these "operations" of Piaget have little correspondence in observable behavior. Many of the more advanced operations are also not generalizable over many cases but require particular qualifications and modifications peculiar to the specific problem task under consideration (Flavell, 1966, pp. 165, 169, 176, 200, 201). The second reason is that Piaget has allowed the subject to determine, not identify, which variable would be controlled.

3. <u>Name coordinates of points in two- or three-dimensional graphs</u>--This objective involves the representation of space in terms of rectangular coordinates. This has been discussed under space-time relationships above. It also involves the logical multiplication of two or more asymmetrical series of relations, which is

Piaget's grouping VII and which is discussed above under the first objective in the Communicating category.

4. Construct a three-dimensional graph of triplets of events--This objective involves the same Piaget operations as those described under objective 3 above.

5. Describe in words the trend or trends shown by the curve in a graph--This objective requires all the skills stated in the above 4 objectives and in addition involves the encoding of these relationships into verbal symbols. Braine has shown that the ability to verbally encode such relationships lags behind the grasping of the relationships themselves (Braine, 1959, 1962). Garner (1962) and other information theorists have done some work on language encoding of perceptual relationships but few studies have been done with encoding of complex logical relationships.

6. Given a graph, identify corrections or additions which will help the graph to communicate--In addition to requiring the skills in the previous 5 objectives, this objective again involves logical decentration, divergence of interpretation and is essentially unique from the other 5 as it relates to Guilford's flexibility which has been previously discussed.

Measuring

1. Order objects from most to least of same property all the objects have in common -- Such as length, or mass or volume -- This objective clearly corresponds to Piaget's operation of addition of asymmetrical relations called grouping V or seriation (Flavell, 1966, pp. 180-181). This operation is clearly defined in the theoretical literature and has been studied extensively.

2. Measure an object using an arbituary unit, such as the width of your hand, or the volume of a drinking glass -- This objective requires the conversion of intensive logical elements to extensive infralogical elements which are used by iteration in measurement operations (Flavell, 1966, pp. 198-199). Here the unit is an arbitrary one of the students choice.

3. Measure an object using standard units from the metric system -- micron, millimeter, centimeter, decimeter, meter, gram, milliliter, liter, newton, degree celsius, seconds, minutes, hours, days, weeks, and years -- This objective is identical to the preceding objective 2 except that the iterable units are the ones which although arbitrary are established by convention or authority. Both objectives two and three occur in objective 5 in Numbers and the essential process skills have been discussed there.

4. <u>Measure quantities which combine two or more standard units -- centimeters per second, grams per milliliter, degree celsius per minute, newtons per square meter</u> -- This objective again involves the basic infralogical process of iteration which is essential to all measurement. However, the units which are used to iterate are conceptual units formed by the appropriate conjunction of perceptual or logical attributes. Therefore, Bruner's work on relational concepts pertains to this objective as does Piaget's operation grouping V11. It is the logical multiplication of two or more asymmetrical relations which leads to the conceptualization of a relational concept. The relational concept may be expressed as a new asymmetric series of relations between events or objects and iteration may be used to measure the amount of the "new" property a given event or situation has (Bruner, 1966, pp. 168-182; Flavell, 1966, pp. 194-199). The grouping V11 operation is required for a number of the above objectives and has been discribed above.

5. <u>Estimate measurements of length, area, volume, temperature, and others using arbitrary or standard units</u> -- This objective is most closely related to the experimental work which has been done in perception, especially in the area of perceptual constancies (Wohlwill, 1960; Itrelson, 1951).

6. Convert a measurement expressed in one metric unit into another metric unit, such as measurement in centimeters into millimeters -- This objective involves once again the ability to logically decenter and to use a new unit to iterate. It may also be conceived as involving the infralogical equivalent of the primary addition of classes (grouping I) since a number of smaller units may be stated equivalent to a larger unit. Again iteration is involved as in all measurement. All these points have been discussed above.

Inferring

1. Distinguish between an observation and an inference -- This is essentially the same as objective 2 under Observing. This requires the subject to actively seek to recognize and separate the denotative and connotative aspects of his perception. This has been discussed under the section dealing with the Observing category.

2. Identify observations which support an inference -- This objective involves the testing of an inference by using the inference deductively to generate particular observations which confirm or fail to confirm the inference. It is analogous to the convergent part of Guilford's creative thinking or problem solving process (Guilford, 1962). It is also analogous to the deductive part of the hypo-deductive reasoning process characteristic of formal operational thought and studied extensively by Piaget (Inhelder and Piaget, 1958; Flavell, 1966, 204-205). However, it differs from Piaget's formulation

in that inferering is used in SAPA in a narrow concrete, non-propositional way (Commentary, pp. 143-144).

3. Construct one or more inferences from a set of observation -- This is clearly the inductive part of problem solution behavior. It has been studied extensively by Bruner, Goodnow, and Austin (1956) and by Bruner et. al. (1966), and by Osler and Fi el (1961) and Osler and Kofsky (1965, 1966). This again involves the ability to logically decenter in order to abstract common properties of a series of seemingly unrelated stimuli.

4. Describe additional observations which would test alternative inferences based on a set of observations -- This objective essentially involves the deductive use of inferred generalizations to generate new areas o investigation. This involves what Bruner (1957) calls going beyond the information given, for the purpose of modifying or making the inference more generalizabl . Inhelder and Piaget (1958) have also studied this process. It is the essential process involved in the testing of inferred propositions in the formal operational mode of propositional reasoning (Flavell, 1966, pp. 205-206).

Predicting

1. Distinguish a prediction from a guess -- This objective primarily relates to a strategy consideration. The "guess" in SAPA approximates the random strategy observed by Bruner et. al.

(1956, Chapters 4 and 5) in his work with the stimulus array, while predicting in SAPA approximates the use of an ideal selection strategy such as conservative focusing (p.87). The guess is an unconstrained prediction. The prediction is a highly constrained prediction with a much higher probability of being valid. Constrained prediction is the objective of this portion of SAPA (Commentary, 1965, p. 151).

2. Use a graph to interpolate or extrapolate -- This objective involves the infralogical multiplication of two or more asymmetric series of relations which has been described above under Numbers, Communicating and Measuring. In addition this objective involves the "going beyond the information given" by the deductive application of a generalized inference procedure discussed in the above section on Inferring.

3. State predictions by interpolating between observed events --

4. State predictions by extrapolating beyond the range of observed events -- These objectives involve both of the above objectives in this section as well as the additional ability to symbolically encode the predictions in language. The behavior central to these objectives has been considered under the fifth objective in the section on Communicating.

5. Carry out appropriate observations to test your predictions -- This objective is essentially the same objective as number 4 in the section on Inferring. The only real difference is that this

objective demands only the concrete procedure of observing, while the earlier objective involves the verbal encoding of the procedure.

6. Order a set of predictions as to your confidence in them; that is, to identify the "shakiness" of a prediction -- This objective clearly involves the infralogical equivalent of Piaget's group V, seriation. Here extensive numeric probability relationships are seriated and their sequence and magnitude are used as the bases for decision processes. This process in humans has been extensively studied in signal detection theory and ROC curves (Clarke, 1960; Swets, 1961; Tanner, 1960).

CONCLUSION FOR THE BASIC PROCESSES

It has been possible to interpret some of the basic SAPA objectives in a fairly precise way in terms of psychological constructs. However, this was not possible for all the objectives. In addition, the dependence of the later objectives upon the preliminary ones is noticably apparent. This same dependence continues into the next set of objectives for the intergrated activities. These objectives also become more and more non-definable in precise psychological terminology as they approach the realm of prevaling cognitive strategies and styles rather than well defined cognitive skills or processes.

THE INTEGRATED PROCESS OBJECTIVES

Formulating Hypotheses

1. Distinguish between inferences and hypotheses -- It is clear that SAPA makes a distinction between these two which is analogous to Piaget's emphasis upon the extent to which concrete and formal operational children generalize their inferences (*Commentary*, 1965, p. 167). Both concrete and formal operational children form rules based upon observation. However, the concrete child's rule extends only to the particular and concrete situation at hand, while the formal operational child seeks a rule of wide generalization. This is clearly emphasized by the marble gun experiment of Inhelder and Piaget (1958, pp. 3-19). The ability to distinguish between a unique and a generalized inference is clearly what is involved in this objective.

2. Construct a hypothesis, given a set of observations and/or inferences -- There are two aspects to this objective although they essentially involve the same process. Constructing an hypotheses from a set of observations has been extensively studied in concept and principle learning. The work of Bruner *et. a* (1956) with the stimulus array is concerned with this aspect of behavior as is the work of Osler *et. al.*, (1961, 1961, 1965, 1966, 1966) and many others. The same sort of inductive process is

used to abstract a higher order generalization based upon a series of first order generalization. This process which is required by the latter part of this objective has not been widely studied. However, Piaget has studied this problem and it is this ability to manipulate propositions which Piaget views as being the essential characteristic of formal operational thought. This requires the individual to take the results of concrete operations, cast them in the form of propositions and to proceed to operate further upon these by logical operations (Flavell, 1966, p. 205). It is this ability which is the primary concern of Inhelder and Piaget in their 1958 text.

3. Construct a test of a hypothesis -- This objective involves the deductive application of a hypothesis to select specific events, situations etc. which will confirm or modify or not-confirm the original hypothesis. This behavior has been studied by Bruner et. al. (1956) in the case of selection strategies, and more recently by Mosher and Hornsby (Bruner, et. al., 1966, pp. 86-102) as well as by Odom and Coon (1966), and Weir (1964), and many others.

4. Identify data from a test which support or do not support a hypothesis -- This objective is concerned with the recognition of positive and negative instances in relation to the hypothesis being tested. Again the work of Bruner et. al. (1956)with the stimulus array is related to this objective.

5. Construct a revision of a hypothesis on the basis of data collected from a test of the hypothesis -- This objective involves inductive reasoning in that further specific instances are used to formulate a new or modified general rule. Again this process has been carefully studied by Bruner et. al. (1956) with the stimulus array in the selection strategy situation (Chapter 4).

Defining Operationally

1. Identify variables or words for which an operational definition is needed, given a hypothesis, inference, model, question, graph, or table of data -- This author knows of no psychological theory or practice which corresponds directly with this objective. However, this objective does seem to involve, to some extent, the separation of relevant variables from irrelevant variables. Inhelder and Piaget (1958, pp. 46-66) have studied this process but not in a way completely analogous to this objective. Their efforts were directed toward how children experimentally identify and separate the relevent variables in an active ongoing problem situation rather than in a static interpretation situation. Furthermore, nothing was said about operational definitions.

2. Distinguish between operational definitions and non-operational definitions of the same object, event, or idea -- Again this author knows of no direct correspondence between psychological theory and this objective. However, an examina-n of the SAPA activities (Commentary, 1965, pp. 181-189)

in this area seems to indicate that the basic difference between operational and non-operational definitions is in the amount of uncertainty each is capable of reducing in the communication theory sense. If this observation is correct, the work of Garner (1962, 1966), Posner (1964), Fitts and Posner (1967) and many others undoubtedly has bearing upon this objective.

3. Construct an operational definition which adequately describes an activity, object, or property of an object in the context in which it is used -- This objective obviously requires the above two objectives. In addition it requires an encoding process which has been discussed under Communicating, objective 5.

Controlling Variables

1. Identify variables which may influence the behavior or the properties of a physical or biological system -- This objective is clearly related to the work of Inhelder and Piaget (1958, pp. 46-79) concerning the separation of relevant from irrelevant variables and the exclusion of irrelevant variables. This, according to Piaget, is accomplished by the "schema of all other things being equal" (1958, pp. 46, 62). Bruner *et. al.* (1956) also have studied this process but with their more abstract stimulus array. Still, these researchers found the same schema to be the *one* approach which consistently produced success in a task where the appropriate variables had to be identified. Bruner (1956, pp. 87-88) calls this schema the ideal selection strategy of conservative focusing.

2. Identify variables which are held constant, manipulated, or responding in an experiment -- This objective is essentially the same as the above objective, except that the role of the subject is more passive. In this situation he is apparently presented with the finished design and results of an experiment and asked to identify how various variables were used (Commentary, 1965, p. 200). This is somewhat analogous to the work of Bruner et. al. (1956, pp. 126-155) with reception strategies. Again they found the ideal strategy to be essentially equivalent to what Piaget calls the "schema of all other things being equal."

3. Describe an experiment using correctly the terms variable, constant variable, responding variable, and manipulated variable -- This objective involves the above 2 objectives and in addition involves the learning of the SAPA names for each type of variable or attribute followed by language and graphic encoding of what has been observed in terms of the appropriate symbols. The encoding process has been described above under Communicating and in several other places.

4. Distinguish between conditions which hold a given variable constant and conditions which do not hold a variable constant --5. Construct a test to determine the effects of one or more variables on a responding variable -- 6. Identify, name and test alternative variables which were not held constant and which may have influenced the responding variable in an experiment -- These three objectives involve the application of the "schema of all other things being equal" as well as the encoding skills discussed in the above objectives.

The entire book of Inhelder and Piaget (1958) is directly related to these objectives, with the flexible rods experiment and the other 5 experiments in part I seeming to be most relevant.

Interpreting Data

1. Describe in a few sentences the information shown in a table or graph -- This is essentially the same objective as objectives 5 and 6 under Communicating. It differs only in that the encoding involves the use of new symbols which have been learned in the SAPA activities up to this point.

2. Construct one or more inferences or hypotheses from a comparison of the information in two or more related tables of data graphs -- This objective involves the use of the logical operations of Piaget and their infralogical equivalents upon generalizations and inferences themselves rather than upon concrete, raw data. This is what Piaget calls propositional thinking or second order inductive reasoning. This procedure is typical of formal operational reasoning according to Piaget (Flavell, 1966, pp. 205-211). This same higher order inductive reasoning process is also viewed as being the essential process in the construction of higher order inferences and generalizations or theories (Lachman, 1960).

3. Apply rules to determine the mean, mode, median, range, and frequency distribution of a set of data -- This objective involves the deductive application of a few general rules which are given in the SAPA Commentary (1965, pp. 211-212). This is the most widely used, if not stated, objective in most conventional science instruction.

4. Use the mean, mode, median, and frequency distribution to describe certain kinds of data and construct predictions, inferences, or hypotheses from this information -- This objective involves the ability to encode data into the appropriate statistical symbols which have been taught by SAPA, and which represent special kinds of generalizations about the data. The second part of this objective involves the second order process of infralogical operations upon these statistical generalizations. This is propositional reasoning which has been discussed under objective 2 above.

5. Construct inferences or hypotheses from pictoral data -- This objective seems to require many of the skills aimed at by the objectives in the section on Formulating Hypotheses. This objective is also closely related to objective 5 in Communicating. It also involves the observational and classification skills developed in Observing and Classifying. It undoubtedly involves the use of second order inferences or propositional thinking, based upon logical manipulation of inferences made from observations and therefore involves objective 2 in this section. This is just a third way to present data. Previously SAPA has presented it in tabular and graphic form. Examination of the

activities on pages 213 and 217 seem to confirm these statements (Commentary, 1965).

Formulating Models

1. Identify a model consistent with a set of observations, inferences, or hypotheses -- According to SAPA a model is an inference or hypothesis constructed to explain a set of observations (Commentary, 1965, p. 221). Therefore, this objective is nearly identical with objectices 3 and 4 under Inferring. This process has been studied by Olson in the bulb board experiment where children were asked to identify a spatial pattern consistent with a series of their observations (Bruner, et. al., 1966, pp. 135-153). The work of Garner on pattern recognition (1962, 1966) is also somewhat related to this objective.

2. Construct a representation of a model -- This objective obviously involves the symbolic representation of a model. The process has been studied by Inhelder and Piaget and others. A paper concerning this work has been written by Inhelder (1965). The representations included schematic drawings by the children. This seems to be directly related to the SAPA activities concerned with this objective (Commentary, 1965, pp. 223-228).

3. Construct an expected outcome (inference or observation) based on a model -- This objective involves the making of predictions from a model. It is essentially the same objective as objectives 2, 3, 4, and 5 under the section on Predicting.

The only difference is that here the models used are not strictly bar or line graphs as they were in the earlier case.

4. Demonstrate the use of a model to explain a set of observations -- This objective requires the testing of the prediction made. It is nearly identical to objective 5 under the section on Predicting.

5. Construct a modification of a model given a model and a set of additional observations, inferences, or hypotheses -- This objective is nearly identical to objective 5 under Formulating Hypotheses and objective 2 under Interpreting Data. Logical decentration is required here, which is the "flexibility" part of Guilford's creative process. Here, however, the logical decentration and cognitive reorganization are at the second order generalization level of propositional reasoning, since previous inferences and hypotheses are being logically manipulated.

Experimenting

1. Distinguish between a description of an experiment which tests a prediction, or hypothesis, and one which does not -- This objective involves all of the objectives listed under the section called Formulating Hypotheses.

2. Identify and name variables in an experiment which the experimentor failed to hold constant for the purpose of experiment -- This objective involves all of the objectives

under the section called Controlling Variables.

3. Construct alternate interpretations from those described in a report of an experiment -- This is again essentially the same objective as objective 5 under Formulating Hypotheses, objective 2 under Interpreting Data, and objective 5 under Formulating Models. As in the previous cases, divergent interpretation and logical decentration are required at the second order or propositional reasoning level.

4. Construct a report of an experiment so that another person can replicate the experiment -- This objective involves the use of all the skills stated as objectives under th [illegible]on called Communicating as well as many of the objectives [illegible]d with various types of communication under each of the sections.

CONCLUSION

It is apparent that the AAAS science process obj[illegible] as stated and described in the commentary form a hiera[illegible] with the objectives on the higher end of the scale sub[illegible] the objectives on the lower end. This is true to a la[illegible] extent throughout the entire sequence of process skil[illegible]ves. It is also apparent that most of the more basic proc[illegible]ors which are stated as objectives have been studied in s[illegible] by psychologists. However, the correspondence betwe[illegible]aviors studied and the stated AAAS process behaviors is fre[illegible]ot

as direct as would be convenient. This condition does not reflect upon the quality of the AAAS curriculum, but rather the incomplete knowledge of cognitive activity expecially in the realm of high order abstract thinking.

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